FINAL
INTEGRATED
FEASIBILITY REPORT
AND
ENVIRONMENTAL IMPACT STATEMENT

COASTAL STORM DAMAGE REDUCTION

BOGUE BANKS, CARTERET COUNTY

NORTH CAROLINA

APPENDIX C

Geotechnical Engineering

US Army Corps of Engineers
Wilmington District

Appendix C: Geotechnical Analyses

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1.0 INTRODUCTION

The results of the geotechnical investigation for the Feasibility Report for the Bogue Banks Coastal Storm Damage Reduction Project are presented in this appendix. A number of sites were investigated for the determination of quality and an adequate quantity of material appropriate for borrow and placement of sand for storm damage reduction. This appendix presents the results of the geotechnical investigation and the compatibility analysis for the Bogue Banks Shore Protection Project for Emerald Isle, Indian Beach, Pine Knoll Shores, Atlantic Beach, and Fort Macon, Carteret County, North Carolina. A number of sites were investigated for the determination of quality and quantity of material appropriate for the placement of sand on Bogue Banks. The sites investigated in this study are present in Figure C-1, and include the Beaufort Inlet Ebb Tide Delta, Bogue Inlet, and various sites offshore of Bogue Banks.

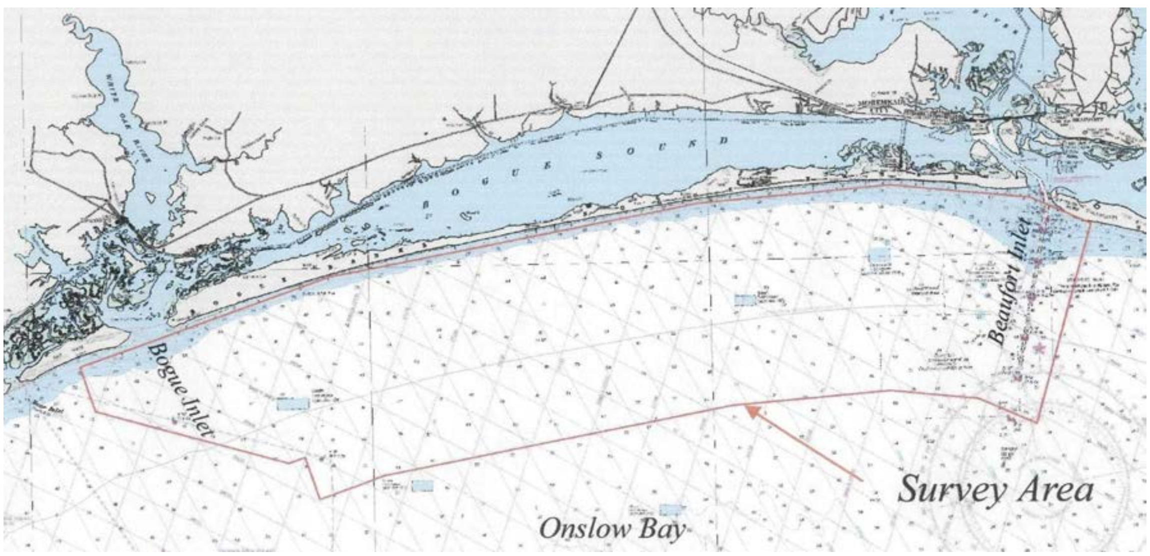

Figure C-1. Bogue Banks Site Map.

2.0 REGIONAL GEOLOGY

The study area encompasses Bogue Banks and nearshore Onslow Bay. Bogue Banks is a 25.4 miles long, south-facing barrier island located on the low-energy limb of the Cape Lookout foreland within Carteret County. The island is bound to the north by Bogue Sound, a relatively shallow water body through which the Atlantic Intracoastal Waterway passes. Present on Bogue Banks are beaches, dunes, and marshes, landforms typical of barrier island complexes. On the nearshore floor of Onslow Bay there are submarine scarps, shoals, and bars.

The Atlantic Coastal Plain and the inner continental shelf of Onslow Bay are both underlain by relatively flat-lying sedimentary units which gently dip and thicken to the southeast. This large sedimentary wedge includes both sediments, which have not been indurated or cemented and rock units. The deepest units were deposited during the Cretaceous Period, from 65 to 144 million years before present (ybp). The youngest part of the wedge dates to the Quaternary Period, from 10,000 to 1.8 million ybp. This sediment and sedimentary rock wedge overlies pre-Mesozoic (older than 248 million years ago) crystalline basement rock (Horton and Zullo, 1991). A patchy veneer of Holocene (10,000 ybp to present) sand and gravel overlies the Quaternary strata in the project area.

Dynamic coastal processes have continually shape the barrier islands of southeastern North Carolina. The rivers and streams entering Onslow Bay are generally small with low gradients. Their continentally derived sediment loads are therefore not very large. In addition, much of this fluvial sediment becomes trapped within the river estuaries. This lack of significant sediment discharge into Onslow Bay limits the build-up of nearshore continental shelf sand deposits. In other areas along the Atlantic coast these nearshore deposits are an important source of sand. As in the case of Atlantic Beach, when deprived of this source of sand, seasonal storms and longshore currents can cause episodic severe shoreface erosion and migration (Cleary, 1968; Sarle, 1977; Riggs 1996).

3.0 SITE GEOLOGY

Bogue Banks (a Holocene age barrier island located in northern Onslow Bay) is bounded by Bogue Inlet to the west and Beaufort Inlet to the east and forms part of the southwest limb of the Cape Lookout cuspate forelands. This is a wave-dominated, microtidal (0.9 m tide range) shoreline. Although waves and storms represent the most significant coastal process affecting Holocene sedimentation (mean annual wave height is 1.7 m), the east-west orientation of Bogue Banks provides some shelter from the wave energy experienced along the northeast limb of Cape Lookout. Wide prominent beach ridges and extensive dune fields characterize the general morphology of Bogue Banks (Heron, et al, 1984).

Seaward of Bogue Banks, a complex Tertiary stratigraphic sequence crops out on much of the seafloor. On the inner shelf, close to the island, a relatively thin (less than ten feet) Pleistocene sequence unconformably overlies the Tertiary sediments. Numerous buried cut and fill stream channel structures occur within these units. The channels have been mostly in-filled with fluvial and estuarine sediments (mostly muds with some sand and shell) of mid-Pleistocene age. Generally, there is no evidence of Holocene barrier related sediment within these structures as they have been removed in response to the numerous sea-level fluctuations that have occurred during the Quaternary (Hine and Snyder, 1985).

Onslow Bay is a modern coastal embayment bordered by Cape Lookout to the north and by Cape Fear to the south. This embayment is underlain by sedimentary rock units that range in age from Upper Cretaceous through the Holocene and are associated with the Carolina Platform, a major tectonic component of the trailing-edge continental margin of North America (Snyder et al., 1982). Regional subsidence of this major structural ramp of pre-jurassic crust controlled lateral progradation of the coastal margin. Seaward progradation of the continental shelf occurred primarily during the Tertiary via a succession of onlap and downlap acretional sequences at the shelf edge (Synder et al., 1982). The present outcrop pattern was produced by subsequent beveling in association with severe shoreface truncation during Neogene and Quaternary erosional transgressions (Synder et al., 1982; Popenoe, 1985).

The continental shelf in Onslow Bay consists of a relatively complex sequence of Tertiary strata, which crop out on the seafloor and dip gently seaward. These units are heavily dissected by relict fluvial channels and partially covered by a patchy veneer of Quaternary sands and gravels (Synder et al., 1988). Late Neogene to Quaternary mesa-like erosional remnants of indurated carbonates and calcareous sandstones (locally referred to as hard bottoms or live bottoms) also occur locally in the Onslow embayment (Riggs et al., 1985).

The oldest Tertiary rocks cropping out in Onslow Bay of Oligocene age. They are composed of two basic limestone units, the Belgrade and the Trent Formations, which consist of moldic biomicrudites limestones with interbedded calcarenite sands and grayish-green calcareous quartz sands (Riggs et al., 1985). A major unconformity separates these rocks from the overlying Miocene Pungo River Formation. Four regional unconformities subdivide the Pungo River formation into three major depositional sequences. Each of these sequences reflects deposition during sea-level cycles in excess of one million years duration. In turn, these stratigraphic sequences are comprised of at least sixteen smaller scales depositional sequences formed in response to sea-level cycles of 100,000 to 1 million-year duration (Riggs et al., 1985). All these depositional sequences are characterized by a lithology that grades upward from muddy, quartz sand or fine sandy and silty mud; to phosphatic, muddy quartz sand or muddy, sandy phosphorite, to cherty, dolosilty quartz sand, fossiliferous micrite, or shell hash. In general, the Miocene rocks that crop on the continental shelf in Onslow Bay; consist of interbedded phosphate sands, variably phosphatic silts and clays, diatomaceous clays, limestones, and dolomite (Snyder et al., 1988).

Patches of Pliocene and Quaternary sediments unconformably overlie the Miocene Pungo River Formation. The only Pliocene depositional record preserved on the inner-to-middle continental shelf of North Carolina is limited to a few calcarenite caprocks, which have become the seed for modern hard ground environments. In addition to this, and because of severe shoreface truncation Neogene and Quaternary erosional trangressions, the shelf stratigraphic record of multiple Quaternary glacioeustatic sea-level fluctuations is almost totally restricted to paleofluvial channel-fill sequences. These channels can be traced many miles; they are up to eighty feet in subsurface relief and up to six miles wide (Hine and Snyder, 1985). The channels in the inner shelf of Onslow Bay are lower coastal plain streams that were in-filled with estuarine and shelf fossiliferous muds and sands. Dates obtained from analyzing vibracore samples taken from these channels indicate that most of the infilling was completed during the mid-Pleistocene sea level transgressive flooding event (Belknap, 1982) and none of them have been associated with Holocene infilling.

4.0 SUBSURFACE INVESTIGATION

4.1 GEOPHYSICAL INVESTIGATION

Ocean Survey Inc. (OSI) performed a geophysical survey offshore of Bogue Banks. A search for suitable beach fill materials for this project was begun offshore in Onslow Bay. A marine geophysical investigation was conducted by OSI, January 8 to January 29, 2002, in order to locate and evaluate potential sand resource areas. Approximately 350 miles of bathymetric and subbottom data were collected along 40 tracklines. Five tracklines were shore-parallel and 35 tracklines were performed perpendicular to shore along with 5 diagonal tie lines to insure thorough coverage. For the trackline locations see Figure C-2.

Geophysical data was collected in the area between 1.0 nautical miles (30 foot isobath) to 6.0 nautical miles offshore of Bogue Banks. The site stretches nearly 24 nautical miles from Bogue Inlet to northeast of Beaufort Inlet. The survey limits were established to further resolve sand resource areas identified by earlier surveys.
Two types of sub-bottom methods were used: a “CHIRP Sonar” seismic reflection profiler, which generates a high frequency, short duration acoustic pulse providing high resolution of shallow sub-bottom strata; and a “Boomer” seismic reflection profiler which uses a low frequency pulse to achieve deeper penetration of the sub-bottom strata. These were run simultaneously to achieve the best possible resolution and penetration. Augmenting the seismic equipment was survey equipment that allowed real-time depth sounding, positioning, and motion (heave) corrections.

A differential global positioning system was used to determine position along the seismic lines. Equipment included a Trimble 4000 Global positioning System (GPS) and a Leica MX52R U.S. Coast Guard (USCG) Differential Beacon Receiver interfaced with HYPACK software. Navigation fixes were recorded by an onboard PC every second.

Bathymetric data was collected at a near continuous rate using an Innerspace Model 448 Digital Depth sounder, which operated at a frequency of 200 kHz. Tidal data from the NOAA station in Beaufort, North Carolina were used for tidal corrections.

The Contractor accomplished the high-resolution subbottom profiling utilizing an EdgeTech Xstar Full Spectrum “CHIRP” Subbottom Profiler system operating with frequencies of 0.5-12 kHz. The system has three components: a deck unit that is comprised of a PC system and amplifier, an underwater cable, and a Model 512 towed vehicle that houses the transducers. The tow fish vehicle emits a high frequency FM pulse over the full spectrum range of 0.5-12 kHz for a 20 millisecond period, and the acoustic return is received by a hydrophone array, which allows high resolution of the shallow subsurface. The higher frequency yields higher resolution with a tradeoff in lesser depth penetration.

Deeper sub-bottom penetration was accomplished using an Applied Acoustics 100-300 joule “boomer” system comprised of a boomer plate, power supply, hydrophone array, TSS-model 360 filter and time-varied-gain system, and an EPC 1086 thermal paper recorder. The “boomer” employs a sound source that utilizes electrical energy discharged from a capacitor bank to rapidly move a metal plate in the transducer bed. The short duration motion of the metal plate creates a broad-band (500-8000 Hz) pressure wave capable of penetrating hundreds of feet of marine sediments under favorable site conditions.

The geophysical and bathymetric surveys showed that shallow rock scarps and outcrops dominate and control the submarine topography offshore of Bogue Banks. A surficial sand horizon was resolved. However, it is very discontinuous and broken by Oligocene rock outcrops. Erosion and reworking of this rock contributes coarse and fine-grained materials to the surficial sand. This decreases its aesthetic value as beach fill. The thickest sequence of unconsolidated sediment occurs in or adjacent to the paleochannels. These sediments tend to be dominated by estuarine muds and fine sands and thus unsuitable as beach fill. The borrow areas must generally be configured to avoid these channels.

OSI used the results of the geophysical survey to recommend boring locations. These locations were concentrated in areas that showed promise for use as borrow sources for sand. The boring locations were also sited in areas that may not contain sand suitable for use as beachfill to verify the interpretations from the geophysical survey.

Figure C-2. OSI Geophysical Tracklines.

4.2 VIBRACORE INVESTIGATION

The subsurface investigation was performed between April and July 2002. A total of 200 borings were performed in Bogue Inlet, offshore of Bogue Banks, Beaufort Inlet and the Bogue Sound area. The borings offshore of Bogue Banks were located between 1 and 6 miles from the beach, in water depths greater than 30 feet, and at changes in seismic profile which could represent differing soil types. The borings performed for the Bogue Banks Channel project is designated LB-02-V-1 through LB-02-V-200. For the vibracore boring locations see Figure C-3.

The borings were performed from the USACE Snagboat SNELL using a 3 7/8 inch diameter, 20-foot long, Alpine vibracore drill machine. The sampler consists of a metal barrel in which a plastic cylinder or tube is inserted. After the plastic tube was inserted, a metal shoe was screwed onto the plastic tube and then the metal barrel. The shoe provided a cutting edge for the sampler and retained the plastic tube. An air-powered vibrator was mounted at the upper-most end of the vibracore barrel, and the vibrator and the vibracore barrel was mounted to a stand. This stand was lowered to the ocean floor by the SNELL's crane; the vibrator was activated and vibrated the vibracore barrel into the ocean sediment. The sediment sample is retained in the plastic tube. All borings were drilled to a depth of 20 feet below the ocean floor, unless vibracore refusal was encountered. Vibracore refusal was defined as a penetration rate of less than 0.1 feet in 10 seconds.

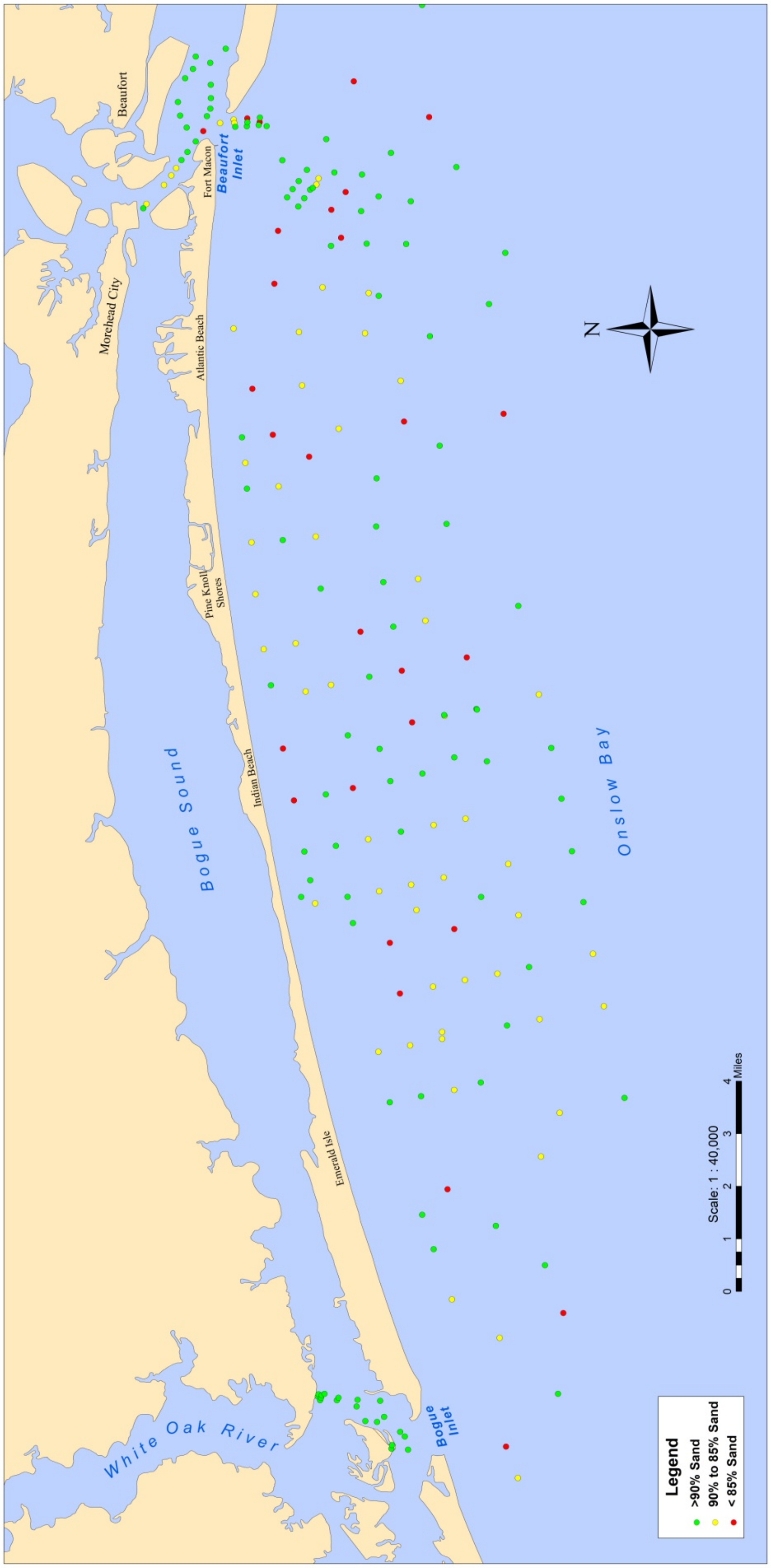

Figure C-3. Vibracore Boring Locations.

5.0 LABORATORY ANALYSIS

The recovered vibracore tubes were visually classified by Wilmington District personnel in accordance with the Unified Soils Classification System (USCS). Representative samples were taken at a minimum of every two feet or at each change of material. A total of 1400 samples were collected in the Bogue Banks area, of which 1369 samples were tested for this project. The grain size tests were performed in accordance with ASTM D-422 using a fifteen-sieve test and visual classifications were performed in accordance with ASTM D-2488, by Wolf Technologies, Inc. The sieves used in these tests were the 3/4, 3/8, #4, #7, #10, #14, #18, #25, #35, #45, #60, #80, #120, #170, and #200. The boring logs and the grain size test results are in Attachment 2.

6.0 NATIVE BEACH SAMPLING

The sampling locations consisted of a total of 25 transects, with 2 transects in Fort Macon, 5 transects in Atlantic Beach, 6 transects in Pine Knoll Shores, 2 transects in Indian Beach, 7 transects in Emerald Isle, and 3 transects in the Bogue Inlet area west of Emerald Isle. The sampling transects for Bogue Banks are presented in Figure C-4. The native beach was sampled in February, 2002. The sample locations are the toe of the dune, crest of the berm, mean high water (MHW) at an approximate elevation of +2.5 feet above mean sea level, mean low water (MLW) at an approximate elevation of -2.5 feet below MSL, and at 2-foot elevation increments from -2.0 feet below MSL to -24.0 feet below MSL as shown on Figure C-5. The samples were obtained with an ocean bottom grab sampler. The sieves used in the grain size testing were the 3/4”, 3/8”, #4, #7, #10, #14, #18, #25, #35, #45, #60, #80, #120, #170, and #200 sieves. The visual percent shell content of each sample was also determined.

Table C-1. Bogue Banks Native Beach Sampling Transect Coordinates.

Location	Grab Profile	2001 Station	Easting	Northing	Azimuth
Fort Macon	1	1019.94	2696659.50	352301.80	178.40
Fort Macon	2	4057.10	2693648.30	352128.90	176.10
Atlantic Beach	3	7048.38	2690763.10	352511.40	188.50
Atlantic Beach	4	11104.32	2686747.80	352878.60	184.60
Atlantic Beach	5	15125.70	2682742.30	353027.50	183.70
Atlantic Beach	6	20156.67	2677731.10	353015.20	181.70
Atlantic Beach	7	25178.11	2672728.60	352644.10	178.70
Pine Knoll Shores	8	30165.41	2667756.00	352529.50	175.80
Pine Knoll Shores	9	35207.09	2662729.70	352205.50	173.90
Pine Knoll Shores	10	40212.74	2657774.90	351517.50	173.30
Pine Knoll Shores	11	45209.95	2652859.20	350709.80	170.60
Pine Knoll Shores	12	50242.63	2647880.10	349992.10	171.00
Pine Knoll Shores	13	55247.85	2642927.40	349269.30	170.20
Indian Beach	14	60248.46	2638007.20	348388.50	170.20
Indian Beach	15	65251.23	2633113.80	347348.10	169.30
East Emerald Isle	16	70254.13	2628205.70	346384.90	168.80
East Emerald Isle	17	76295.50	2622268.00	345273.30	168.70
East Emerald Isle	18	82261.06	2616419.20	344102.30	167.40
West Emerald Isle	19	89262.34	2609535.80	342870.50	168.20
West Emerald Isle	20	96284.91	2602704.90	341242.10	166.40
West Emerald Isle	21	103359.23	2596043.40	338965.40	163.90
West Emerald Isle	22	110390.23	2589324.50	336992.00	164.10
Bogue Inlet Area	23	117403.30	2582665.30	334847.00	161.40
Bogue Inlet Area	24	123418.00	2576946.30	333040.50	159.70
Bogue Inlet Area	25	127403.67	2573233.50	331621.70	164.90

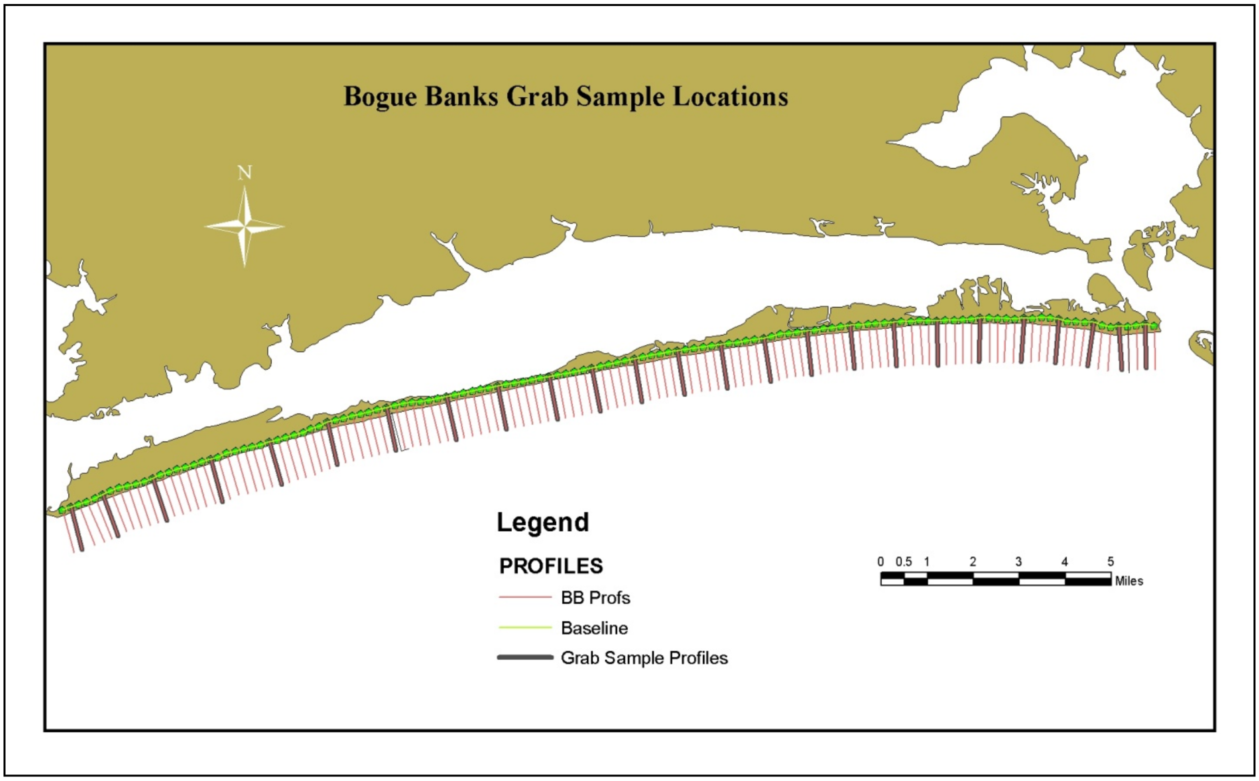

Figure C-4. Bogue Banks Native Beach Sampling Transects.

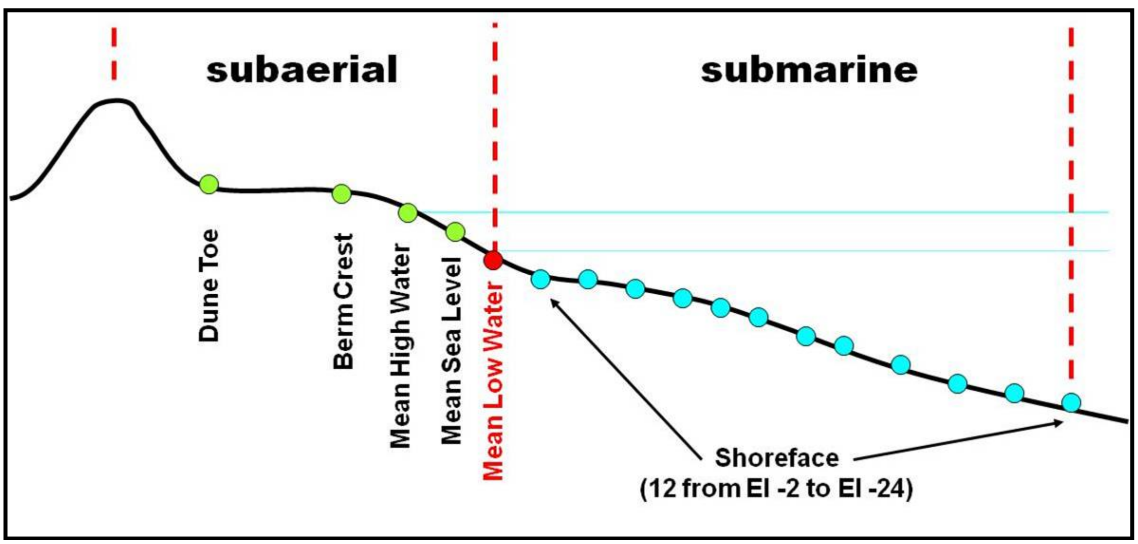

Figure C-5. Bogue Banks Beach Grab Sample Locations Along the Beach.

7.0 BORROW AREA SELECTION

The borrow sites for this project were selected through an iterative process to find the most economic and best quality material for use as borrow. After the completion of the vibracore borings, the usable sand thickness in each boring was estimated. The thickness and location of the vibracore boring were plotted in the Bentley Microstation computer program. The program was then used to estimate contours of the approximated sand thickness over the entire area. For the sand thickness contours see Figure C-6.

Figure C-6. Geophysical Tracklines and Boring Locations with Sand Thickness Contours.

The locations that appeared to contain a significant area and had usable depths of sand greater than 2 feet in thickness were identified. The preliminary areas identified for potential use for Bogue Banks Beach project borrow were Bogue Inlet, N, P, Q1, Q2, R, S, T, U, V, X, Y, Z, the Morehead City Harbor Channel, and Bogue Sound (see Figure C-7).

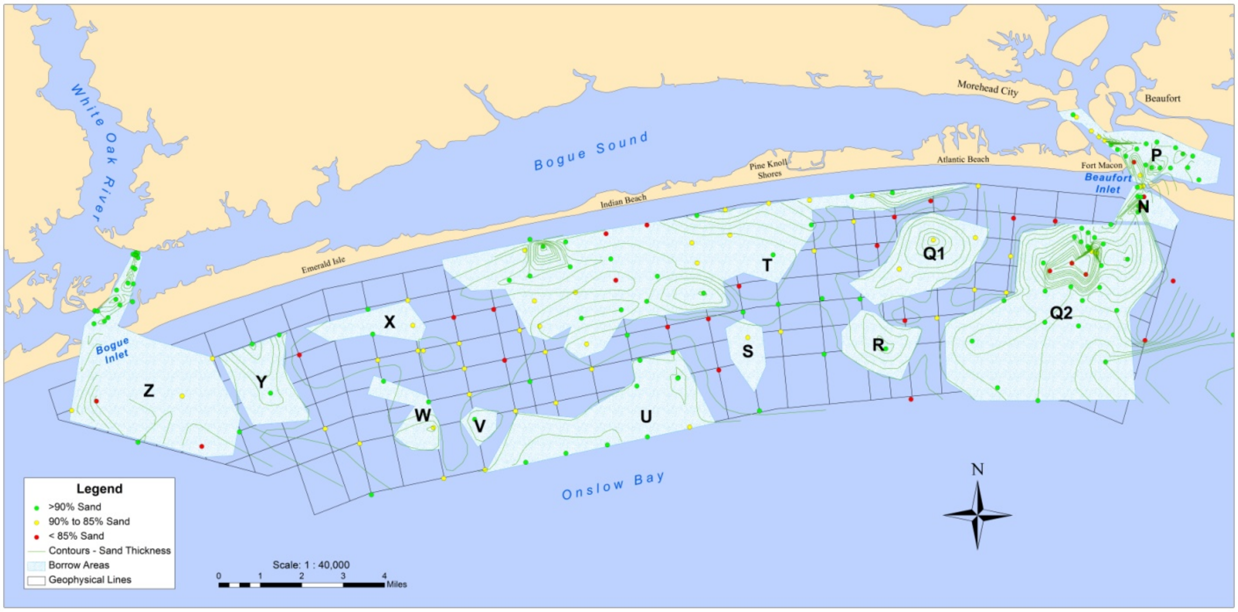

Figure C-7. Initial Proposed Borrow Areas.

Once the lab grain size testing of the vibracore samples was completed, the borrow areas were reassessed to determine the quality of the material in the proposed borrow areas. Some areas such as Area T contained too high a shell content and were eliminated. Other areas with higher silt content were also eliminated from consideration. Also, some other areas which no longer had a large enough quantity of suitable material to use for a full renourishment cycle were eliminated.

An assessment of environmental and archeological features of the remaining areas was performed. Area Q2 was greatly reduced due to the environmental features such as artificial reefs and archeological areas such as the Queen Anne's Revenge and other significant features along the ebb tide delta. Area Q2 was also reduced due to the exclusion of the Nearshore Placement Area.

A compatibility analysis was performed on the remaining potential borrow areas. The compatibility analysis is explained in the Compatibility Analysis section further below in this report. The potential borrow areas were again reduced if the material quality of the remaining material was not of beach quality. Area Q1 is one of these areas that after being reduced due to hardbottom and tire reefs, the remaining material volume and material quality was no longer as high as the remaining proposed borrow areas. The areas remaining as proposed borrow areas are Area Y, Area U, and the Morehead City Ocean Dredged Material Disposal Site (ODMDS) portion of Area Q2 (see Fig C-8).

Figure C-8. Selected Borrow Areas.

It should be noted that potential borrow areas eliminated at this time may not be unacceptable quality material for use as beach fill, they are just not as high a quality and as large a volume as selected areas. They may be reconsidered for use in the future is an increased volume of material is needed.

8.0 VOLUME CALCULATION

Bentley InRoads surface modeling software was used to develop surface models and estimate borrow volumes. Borehole data analysis resulted in a value for thickness of suitable material at each boring location. These material thickness values and their locations were input into InRoads for surface modeling. Bentley InRoads uses the Delaunay triangulation technique to interpolate data and create the surface models. Isopach lines were drawn to represent contours of material thickness. Initial borrow area limits were identified using a minimum estimate of 2 feet of usable material thickness. Other constraints such as locations of hardbottoms and cultural resources were applied to further refine the borrow limits. Final estimates of material volumes and surface areas were calculated using InRoads.

Due to the dredging process, it may not be practical to dredge the full depth of the borrow area. A vertical buffer of 1-foot was considered to accommodate the inaccuracies during dredging. The borrow area volumes were calculated for the full borrow depth and the borrow area with a 1-foot buffer. Based on previous experience with hopper dredges, the 1-foot buffer is reasonable to account for the dredging process. The 1-foot buffer was used to determine the quantities of borrow material available. The volumes of available material in each borrow area with the varying vertical buffers are shown in table C-2.

Table C-2. Bogue Banks Borrow Area Volumes.

Borrow Area	Volume (mcy)	
	No Buffer	1' Buffer
Borrow Area - Y	6.4	4.6
Borrow Area - U	14.4	8.9
Borrow Area - Q2	35.4	28.3

9.0 COMPATIBILITY ANALYSIS

A compatibility analysis involves the comparison of the grain size distribution characteristics of the material existing on the active profile of the native or reference beach and the material available from the proposed borrow area. The native beach and borrow sediments were analyzed using standard sieving techniques. Based on the size distributions of the two materials, estimates can be made of the amount of over-filling required to construct a given design beach profile.

Wave action tends to distribute the material across this active beach profile in discrete size increments. The active beach profile is that portion of the profile regularly affected by wave action and generally extends from the crest of the beach berm seaward to water depths of approximately 24 feet. Samples of the native beach material are collected at uniform depth intervals from the crest of the beach berm seaward to water depths of about 30 feet and the size characteristics of each sample determined by standard sieve analyses. The size characteristics of the individual samples are mathematically mixed to determine composite mean and composite standard deviation of the material that is on the active beach profile.

10.0 COMPATIBILITY REQUIREMENTS (CRITERIA)

The Wilmington District guideline with regard to the percentage of fine-grained sediments is that borrow areas containing more than 10 percent fines are generally considered to be incompatible for placement on the beach due to potential problems with turbidity and siltation during placement. Though the State of North Carolina has recently enacted sediment compatibility criteria, it is not a part of their Coastal Zone Management Program. Therefore, the Wilmington District will continue to follow the no more than 10 percent fines criteria for sediment compatibility.

11.0 NATIVE BEACH CALCULATIONS

The native beach composites were generated to reflect variations in sediment characteristics across the beach profile through varied energy zones, along the beach, at depths within the active profile. Surface samples were combined into one composite average grain-size distribution by summing the weights retained on each sieve interval and then dividing by the number of samples. The composite weight for a given size is:

$$w_{composite} = (w_{S1} + w_{S2} + w_{S3} + \ldots\ldots + w_{Sn})/n$$

where:

$w_{composite}$ = composite weight for a specific sieve
w_{Sn} = sediment weight retained on a specific sieve for each sample
n = number of samples

An analysis was performed with the grain size results of the samples taken to determine the native beach quality values. The values of key criteria was determined for the purpose of comparing potential sources of borrow material. The analysis determined the percent finer than then #4 sieve, the % finer than then #10 sieve, the percent finer than then #200 sieve, and the shell content.

12.0 OVERFILL RATIO

The suitability of the borrow material for placement on the beach is based on the overfill ratio. The overfill ratio is computed by numerically comparing the size distribution characteristics of the native beach sand with that in the borrow area and includes an adjustment for the percent of fines in the borrow area. The overfill ratio is primarily based on the assumption that the borrow material will undergo sorting and winnowing once exposed to waves and currents in the littoral zone, with the resulting sorted distribution approaching that of the native sand. Since borrow material will rarely match the native material exactly, the amount of borrow material needed to result in a net cubic yard of beach fill material will generally be greater than one cubic yard. The excess material needed to yield one net cubic yard of material in place on the beach profile is the overfill ratio. The overfill ratio is defined as the ratio of the volume of borrow material needed to yield one net cubic yard of fill material. For example, if 1.5 cubic yards of fill material is needed to yield one net yard in place, the overfill factor would equal 1.5.

The overfill criteria developed by James (1975) is the method used in the Automated Coastal Engineering System (ACES). The procedure is also described in the U.S. Army Coastal Engineering Manual EM-1110-2-1100 Part V (July 2003).

The overfill ratio for the Native or Reference Beach was compared to the borrow area material was calculated by the Aces Method. Based on the Aces Method, the overfill ratio for is varied between 1.05 and 1.41. Any overfill ratio value of less that 1.5 with a fine content of less than 10% is considered acceptable for use as beach renourishment. For the beach segments for the overfill ratios see Figure C-9. The overfill ratio for each borrow is shown in table C-3.

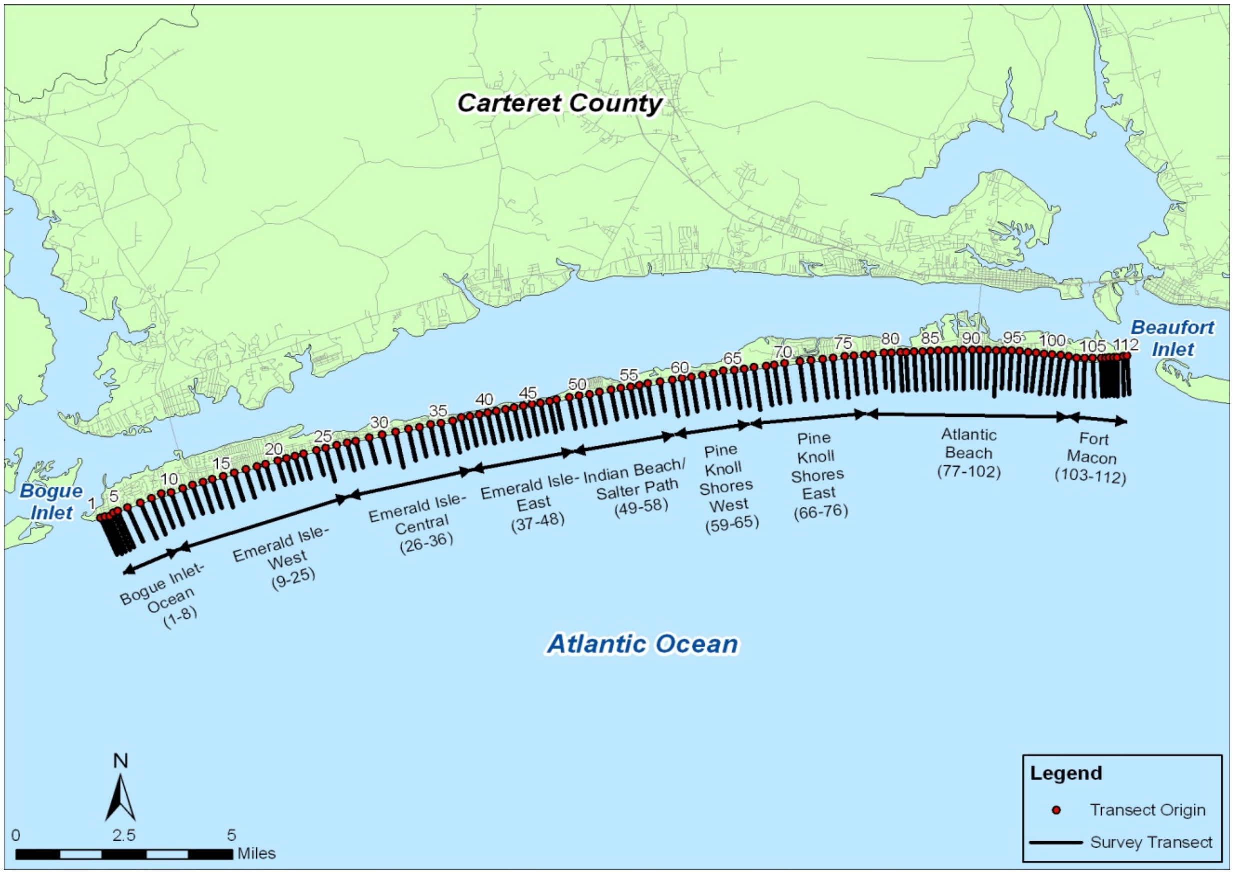

Figure C-9. Bogue Banks Beach Segments for Overfill Ratios.

Table C-3. Bogue Banks Overfill Ratios.

LOCATION	OVERFILL RATIO
Bogue Inlet - Ocean	1.10
Emerald Isle - West	1.05
Emerald Isle - Central	1.05
Emerald Isle - East	1.05
Indian Beach/Salter Path	1.05
Pine Knoll Shores - West	1.05
Pine Knoll Shores - East	1.11
Atlantic Beach	1.07
Fort Macon	1.41

NOTE: The overfill ratio is calculated using the James Method.

13.0 RESULTS

Based on the analysis of the overfill ratio and the grain size analysis borrow areas Q2 (ODMDS), U, and Y were selected as the source of borrow material. The percent passing the #200 sieve is less than 10 percent for all the proposed borrow areas. The grain size distributions for the native beaches and the borrow areas are shown in Table C-4. A total of 41.8 million cubic yards of material is available within the 3 proposed borrow areas. The volume of available material and the footprint area of each borrow area is shown in table C-5.

Table C-4. Bogue Banks Grain Size Comparison.

Location	# of Samples	Mean (mm)	Std Dev (mm)	% Passing # 4	% Passing # 10	% Passing # 200*	% Visual Shell
Native Beach							
Ft. Macon	34	0.21	0.57	99.8	99.0	1.6	10.9
Atlantic Beach	82	0.18	0.58	99.6	98.7	3.4	7.1
Pine Knoll Shores	102	0.19	0.57	99.4	98.4	3.6	8.9
Indian Beach	34	0.21	0.52	99.5	98.2	3.2	10.9
East Emerald Isle	47	0.20	0.60	99.6	98.8	2.6	6.3
West Emerald Isle	67	0.19	0.62	99.4	98.7	2.4	4.9
Bogue Inlet Area	51	0.19	0.70	99.6	99.6	1.9	4.0
Borrow Areas							
Area Y	8	0.28	0.54	92.1	87.7	4.2	8.2
Area U	13	0.23	0.58	98.6	96.2	4.8	11.9
Area ODMDS	14	0.20	0.68	98.5	97.0	3.9	7.1

* % Passing #200 is comparable to % silt

Table C-5. Bogue Banks Borrow Area Footprint and Volumes.

Borrow Area	Borrow Depth (ft)			Footprint Area (acres)	Volume (mcy) 1' Buffer
	Min	Max	Avg		
Borrow Area - Y	2.2	7.6	4.4	1100	4.6
Borrow Area - U	1.4	4.0	2.8	3450	8.9
Borrow Area - Q2	3.1	8.1	5.3	4400	28.3

14.0 CONCLUSION

Based on the total estimated volume in the borrow areas, including the 1-foot vertical buffer, there is an adequate quantity of suitable beach quality material to complete the full 50-year life of the project. There is approximately 41.8 million cubic yards of suitable borrow material available in the 3 proposed borrow areas, Area Y, Area U, and Q2. These volumes do not include any recharge of these areas. Areas to be used for borrow will be further defined during the Preconstruction, Engineering, and Design phase of this project. Additional borings and/or geophysical surveys will be performed to better delineate the borrow area boundaries and material types.

15.0 REFERENCES

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Attachment 1

Final Report Geophysical Survey of Sediment Deposits Offshore Bogue Island Onslow Bay, North Carolina prepared by Ocean Survey, Inc.

Attachment 2

Boring logs with Lab Data

Both Available Upon Request